which represents the relation between yield of wheat for England and the previous autumn rainfall is:

Yield = 39.5 bushels per acre — 5/4 (previous autumn rainfall in inches).

If we call the yield obtained from the rainfall by this equation the "computed yield," a comparison with the actual yield for the twenty-one years shows that the computed yield agrees with the actual yield within half a bushel in seven years out of the twenty-one. In fourteen years the agreement is within two bushels; in the remaining seven years the difference between computed and actual yield exceeds two bushels. The extreme variation of yield in the twenty-one years is nine bushels, from 26 bushels per acre in 1892 and two other years, to 35 bushels per acre in 1898.

Of the seven years for which the formula gives yields differing from the actual by upward of two bushels, 1896 is the most conspicuous; its actual yield exceeds the computed yield by 4.5 bushels.

These seven years all show anomalous seasons. Taken *seriatim*, they are 1887, 1888, 1893, 1895, 1896, 1899, and 1903.

In 1888 and 1903 the crops were washed away by ten inches of rain in the summer; 1893 is the year of phenomenal drought and the crop was below the computed figure by 2.5 bushels. The years 1892 and 1899 are interesting, because, though the amounts of rain were up to the average, the former had eight dry weeks and the latter ten dry weeks out of the thirteen included in the conventional autumn. They were thus dry autumns, the average amount of rainfall being made up by a few exceptionally wet weeks. The yields correspond with dry autumn values. They are above the average and above the computed figures by some two or three bushels per acre.

There remain 1895 and 1896; 1895 was the year of remarkably cold weather, and in that year the yield fell short, but in the following year the deficiency was made up by a yield as much above the computed value as the previous one fell short. It would appear that in this instance the productive power not utilized in the year of the great cold was not lost but stored. On the other hand, it must be remarked that 1896 had the advantage of a specially dry winter.

It appears from these considerations that the dryness of autumn is the dominant element in the determination of the yield of wheat of the following year. The averages of yield and of rainfall are taken over very large areas, and it may be taken for granted that the investigation of the question for more restricted areas would introduce some modification in the numerical coefficients, if not in the form of the relation.

The data for making such an investigation are not yet in an available form. A comparison has been made between autumnal rainfall for "England, East" and the average yield for the counties of Cambridge, Essex, Norfolk, and Suffolk, which shows a similar relation but a magnified effect of autumnal rainfall upon the crop, and also two exceptional years which have not yet been investigated.

CONTRIBUTIONS TO MARINE METEOROLOGY.

Two important contributions to the meteorology of the sea have recently appeared:

1. *Observations océanographiques et météorologiques dans la région du courant de Guinée. (1855-1900.) I. Text et tableaux. II. Planches.* Utrecht. 1904.

This work, which is published by the Royal Meteorological Institute of the Netherlands, is a thorough discussion of the winds, currents, air pressure, air temperature, number of rainy days, surface temperature, and density of sea water for the region indicated in the title. All the above-named features are fully charted. The region covered by this work lies between the parallel of 25° north and the equator, and the meridians of 0° and 40° west.

2. *Wind charts for the South Atlantic Ocean.* Published by the Hydrographic Department of the British Admiralty, January, 1904.

These charts embrace the region lying between the equator and 65° south latitude, and between the meridians of 20° east and 90° west. Except for small areas in the extreme south of this region, for which observations are lacking or insufficient, wind-roses are given for each 5-degree square; and many useful notes are added regarding local peculiarities of wind and weather. The charts include isobars and isothems. The introduction contains a very interesting and practical discussion of the meteorology of the whole region, together with charts showing the distribution and frequency of fog. This work embodies the results of nearly a million observations. Some portions of these results, dealing with the regions adjacent to the South American coast, were published in 1902.—*C. F. T.*

HIGH WATER IN THE GREAT LAKES.

By Prof. ALFRED JUDSON HENRY.

Very great interest has recently centered in the fluctuation in level of the Great Lakes during the last ten years, the revival in interest being directly due to the unusually high water of 1904. A decided rise in level above what may be called normal stages means greatly increased earning capacity, especially for the larger vessels afloat on these inland seas. In a recent issue of the Chicago Chronicle comparisons were made between low water of 1895 and high water of 1904. The extreme range, about three feet, was shown to have occurred on Lake Ontario, and the least range, about one-tenth of a foot, on Lake Superior. The rise on Lakes Michigan and Huron from 1895 to 1904 was shown to have been a little over a foot and a half and on Lake Erie nearly two feet. It should be remembered in this connection that the low water of 1895 was the culmination of one of the greatest droughts this country has ever experienced. In that year severe and prolonged drought centered in the Lake region and the Middle Atlantic States, and the lowest water of a quarter of a century was reached in many of the rivers and small streams. This period of drought was followed by years of plentiful precipitation, and the Great Lakes, as well as the rivers, returned to normal conditions.

Two distinct series of oscillations are recognized on the Great Lakes. The first consists of the annual rise of the waters to a maximum stage in summer, followed by a decline to a minimum stage in winter or spring. The second series is superposed upon the first, and generally extends through a period of several years. It is illustrated on the diagram, fig. 1, by the upward tendency shown on the curve for Lakes Michigan and Huron from 1896 to 1899; also on the curve for Lake Erie, wherein, it will be noticed, the crest or flood stage for each year from 1895 to 1898 is somewhat higher than for the year immediately preceding.

The annual rise in the Great Lakes begins with the breaking up of ice in the tributary rivers and small streams, and the maximum or flood stage is generally reached in midsummer. Owing to marked climatic differences between the northern and southern portions of the Lake region, the spring rise begins about a month and a half earlier on Lake Erie, the most southern lake, than it does on Lake Superior, the most northern. The time of high water on the last-named lake is also from one to three months later than on Lake Erie. The period of replenishment on all of the lakes, except Superior, is from March to June; on Superior from April to September. As soon as high water is reached the lakes begin to fall, slowly at first, but quite rapidly as the winter season approaches.

The annual rise and the nonperiodic variations are doubtless due to atmospheric influences, the most important of which are precipitation, temperature, and evaporation. Changes in lake level may be also due to other causes, such as an increase